DAVIS ENERGY GROUP INCORPORATED

Field Survey Report:

Documentation of Hot Water Distribution Systems in Sixty New California Production Homes

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Legal Notice

1 Background and Objectives

The efficiency of delivering hot water in single family hot water distribution systems is dependent upon many factors including:

- hot water usage characteristics (magnitude, profile, flow rates, use temperature)
- the configuration of the hot water distribution system (HWDS)
- piping installation issues (layout, pipe material type and diameter, insulation)
- location of hot water piping and heat loss environment surrounding the pipes
- water heater setpoint
- location of hot water fixtures relative to the water heater(s)
- recirculation system controls

All these factors play a role in determining how efficiently hot water is transported from the water heater to the end use points. Hot water distribution system performance is a complex issue since the same house may perform very differently based on household usage characteristics (time of day usage patterns, clustering of draws, use temperature, use of tubs vs. showers, etc.)

New homes being built in California are significantly larger and have more amenities than homes built twenty to thirty years ago. One trend that has been occurring is an increase in the number of hot water consuming fixtures. Homes with four and five bathrooms are not uncommon. In addition, multi-head showers and large whirlpool tubs are increasing in popularity. More use points, high flow rate fixtures, and increased house size all contribute to more and larger diameter hot water piping in new homes. This has implications both in terms of energy usage (greater heat loss), customer satisfaction (longer hot water wait times), and water waste (more water is dumped before hot water arrives at the fixture).

To better understand how hot water distribution systems (HWDS) are being installed, Chitwood Energy Management and Davis Energy Group completed a field survey of sixty new production homes. The goal of the survey was to quantitatively characterize the HWDS plumbing layout as well as to collect data on the type of water heater being installed, hot water fixture characteristics, and gather anecdotal feedback from plumbers and building superintendents on industry trends.

In this study we have characterized HWDS as one of the four following types:

- conventional trunk and branch (either copper or PEX[1])
- PEX parallel piping systems with a central manifold feeding either 3/8” and ½” lines or exclusively ½” lines

[1] PEX is a plastic cross-linked polyester piping material common to much of California. There are several building jurisdictions (e.g. Los Angeles and San Diego) that do not allow PEX for potable water applications.

- Hybrid systems (a variation of the trunk and branch system that includes a main trunk(s) and either in-line mini-manifolds or Tees with branches and mini-manifolds)
- Recirculation systems (a central loop with a pump and controls that activate pump operation based on either a timer, temperature input, or an occupant initiated demand for hot water)

2 Field Survey Methodology

The goal of the field survey was to gather a statewide snapshot of current HWDS installation practice in California production homes. Although not statistically significant, it does capture current industry trends and installation practices.

For site selection, the following target geographic breakdown was developed.

Northern Sacramento Valley: ~5 houses
Greater San Francisco Bay Area (S.F, East Bay, South Bay): 5 to 10 houses
Central Valley (Sacramento to Bakersfield): 20 to 25 houses
Southern California coastal (L.A. and San Diego): 5 to 15 houses
Southern California inland (Riverside to desert regions): 10 to 15 houses

As part of the development of the field survey plan, we further segmented the sixty home sample into the following subgroup targets:

- All single family detached homes
- Conditioned floor area (ranging from 1,200 – ~4,000 ft^2, average of 2,200-2,500)
- A goal of no more than three houses per plumbing contractor, although in some markets one or two large contractors may dominate the scene
- Target survey segmentation into the following subsets
  - One and two-story houses: Total of 60, with minimum of 20 each
  - Conventional main and branch systems: 20-35 sites
  - Hybrid systems: ~5-15 sites
  - Parallel piping systems: ~5 sites
  - Recirculation systems: 5-15 sites, with 2-5 demand recirculation
  - Largely underslab piping: ~5-10 sites

The survey will focus on the following key elements:

- Site characterization: location, builder, plumber, floor area, 1 or 2 story, etc
- Water heater characteristics: size, type, volume, location, etc

- Piping system: sketch and tabulation of each installed "segment"[2] of hot water line from the water heater to the end use point
- Hot water use points: fixture type
- Recirculation system type (if installed): make/model #, pump specification, control type
- Underslab pipe description: soil characteristics surrounding underslab piping

Two methods were used to locate and obtain access to the construction sites. The first approach involved using industry contacts to obtain access to sites. HERS raters involved in construction quality verification proved to be the best industry contacts. The HERS raters close connection to projects was useful in identifying sites at the appropriate stage in various subdivisions. Allen Amaro (Amaro Construction Services) helped locate homes in the Sacramento area and Scott Johnson (Maximum Home Performance) helped locate homes in Southern California. Davis Energy Group's work with builders also provided several Northern California sites. The second approach to finding survey sites involved driving onto active job sites to see if they met the site selection criteria and then obtaining permission to survey the site. Permission to survey the site from the superintendent or the plumbing foreman was never denied.

The majority of the construction sites had on-site model homes. The models provided information about how the homes would be finished and the floor plans for the homes to be surveyed. The sales literature provided contained the floor plans for all of the homes in the subdivision, floor plan options, and a description of the energy features and construction methods. The make and model number of water heater was obtained from the water heaters installed in the models except when the garages were locked. Plumbing fixture information (faucet types and shower head type) was also obtained from the models. This information was further documented by taking pictures of the fixtures in the models. Generally the model homes had upgrade fixtures installed. Discussions with sales staff or the plumbing contractor was used to determine typical fixture types.

The key survey element involved measuring every section of installed hot water piping in the home with a tape measure or a measuring wheel and recording the measurement on the field data sheet. Additional data collected included pipe material type, diameter, location, and the presence of thermal insulation. The location of major components such as the water heater, trunks, manifolds, etc. were sketched on the floor plan. Pictures were also taken to document each site. Digital pictures of; installation quality, hot water draw points, underslab terminations, pipe locations, bundling of tubing, and any special features or characteristics further document each site.

All measurements reflect actual installed piping lengths with one exception. An additional 1.5 feet of length was added to the as-built measurement to account for piping to be installed from the garage stub-out to the water heater. The additional 1.5 feet of pipe was assumed to be the same diameter as the pipe penetrating the garage drywall.

[2] A "segment" includes a unique description of the following: pipe material, diameter, environmental location (e.g. under slab, attic, interior wall, etc), and presence of insulation. With this definition a single ¾" pipe may be divided into multiple segments as it moves through, for example, different environments.

For manifold systems, the measurement of the main line from the water heater to the manifold terminated at mid-height of the manifold. An additional volume was added to account for the larger internal manifold diameter relative to the main line[3].

3 Results

The sixty houses surveyed included installations from 19 different plumbing contractors. Sites were geographically located as described in Table 1. The majority of the sites were located in climate zone 12. Although no sites were surveyed in the southern San Joaquin Valley, the geographic range in zone 12 extended from the San Francisco Bay Area commuting communities of San Ramon and Tracy eastward to El Dorado Hills in the Sierra foothills. Nine southern California coastal sites were survey as well as fifteen sites in the greater Palm Springs area. A California climate zone map in Appendix A shows the approximate locations of the sixty sites.

Table 1: Site Location Summary

Climate Zone	Number Of Sites	Location
6	6	San Juan Capistrano, Costa Mesa
8	3	Tustin
10	1	Menifee
11	6	Lincoln, Redding
12	29	Woodland, El Dorado Hills, Elk Grove, Rancho Cordova, San Ramon, Tracy, Mountain House
15	15	Indio, Palm Springs, Desert Hot Springs

Figure 1 plots the conditioned floor area for the sixty houses based on floor plans typically provided as part of the builder sales literature. Conditioned floor area averaged 2,432 ft^2. Twenty-five of the houses were single story (average floor area equal to 2,209 ft^2) and 35 were two-story (average floor area equal to 2,590 ft^2). On average there were 2.84 bathrooms per house and 12.85 hot water use points[4]. Figures 2 and 3 plot the bathroom and use point data as a function of floor area.

[3] To account for an estimated 1.5 feet of 1.25" distribution manifold, 0.07 gallons were added for a ¾" main line and 0.05 gallons were added for a 1" main line.
[4] Combination tub/shower were treated as two use points.

Figure 1: Floor Area Distribution

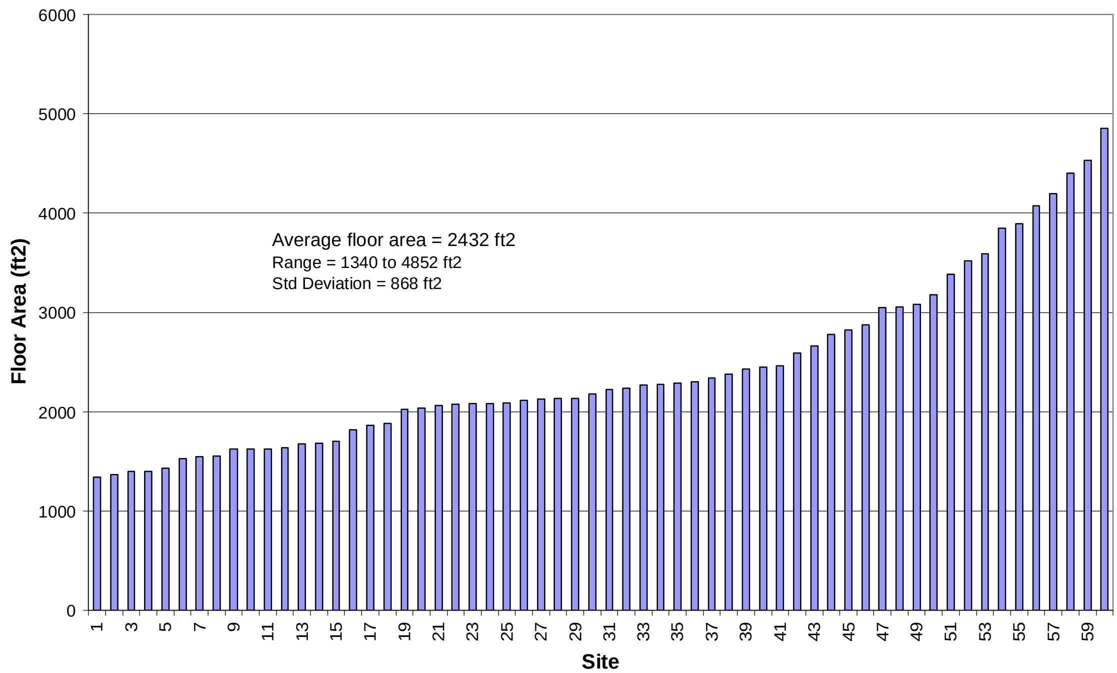


Figure 2: Number of Bathrooms as a Function of Floor Area

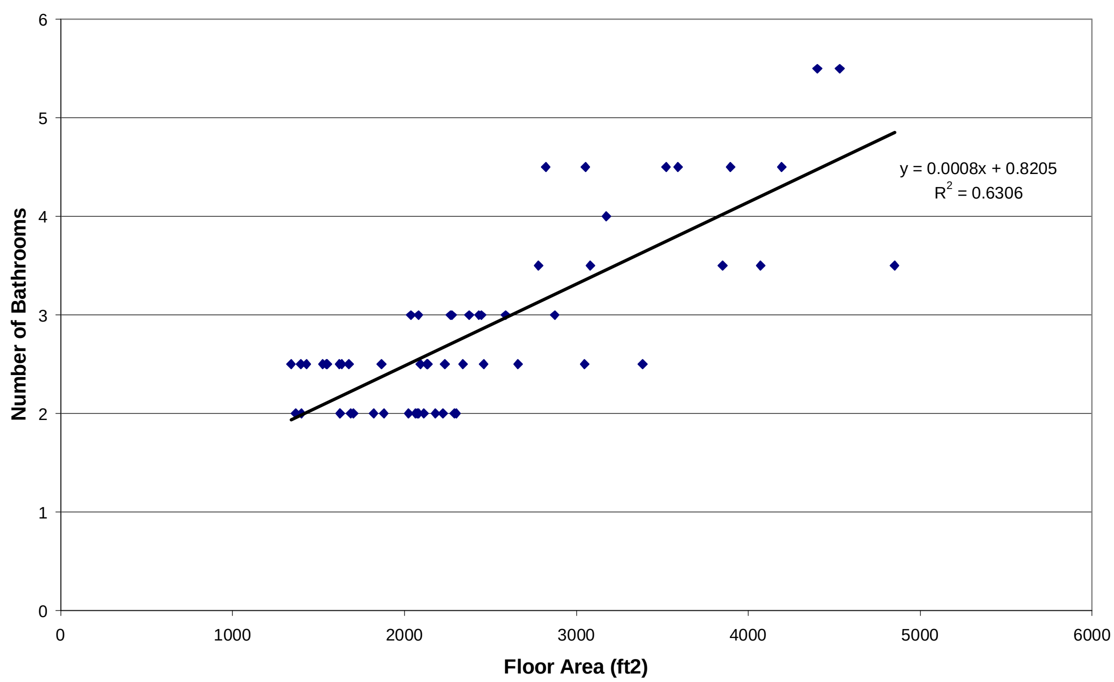


Figure 3: Number of Hot Water Use Points as a Function of Floor Area

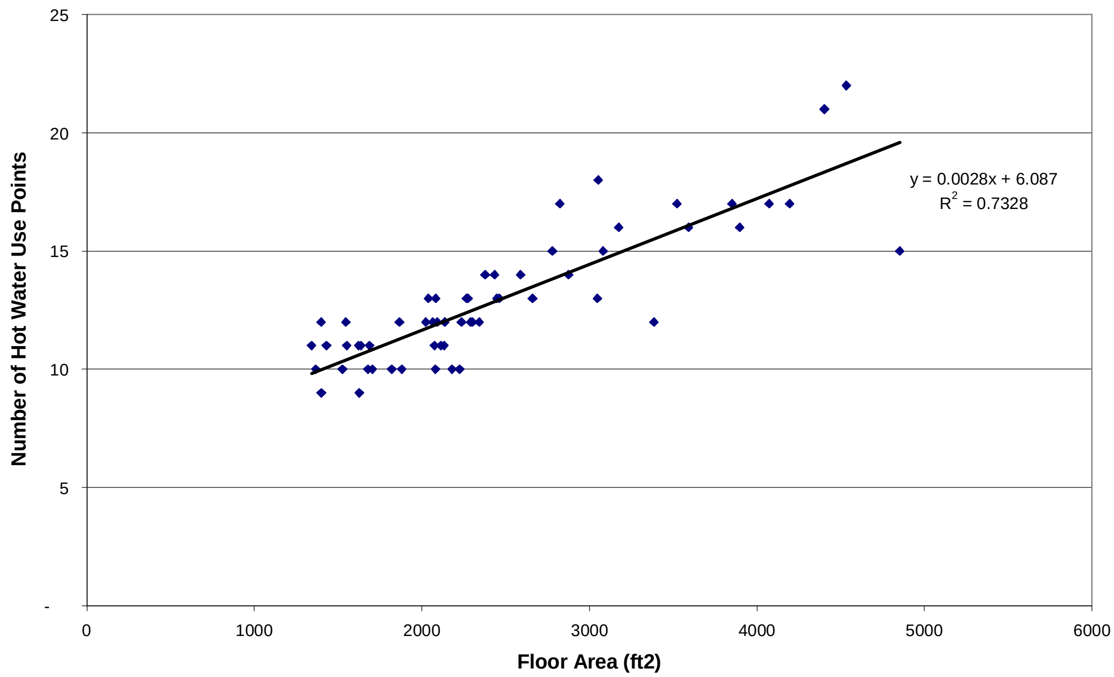


Table 2 summarizes the pipe materials installed in the sixty home sample. A total of 21,996 feet of pipe were measured in the sixty homes (average of 367 feet per house). PEX was the most common material installed (84% by length). None of the 35 houses surveyed north of the Tehachapis utilized copper as the primary piping material. In southern California, nine of the 25 systems were copper systems. No other piping materials besides copper and PEX were found. The righthand column in Table 2 represents the length of piping corresponding to one gallon of entrained volume. For copper piping values are shown for both Type M (typical thin wall pipe) and Type L (required for underslab plumbing). PEX piping, with its greater wall thickness, has roughly 40% less volume per foot than copper piping. This is beneficial from a waiting time and heat loss perspective (assuming all the stored heat is lost between draws), but also results in a faster cool-down time between draws.

Table 2: Breakdown of Pipe Characteristics

Pipe Material	Field Measurements By Length	Field Measurements By Volume	Feet of Pipe Per gallon
1" Copper	3%	10%	22.0 (23.3) *
¾" Copper	5%	10%	37.2 (39.8) *
½" Copper	9%	9%	75.8 (82.5) *
1" PEX	2%	6%	32.0
¾" PEX	9%	15%	52.8
½" PEX	41%	35%	104.2
3/8" PEX	32%	15%	189.1

"*" Volumetric data is reported in terms of Type M with Type L in parentheses

HWDS type was disaggregated into the four categories: conventional trunk and branch, PEX parallel piping systems with a central manifold, hybrid systems, and recirculation systems. Table 3 summarizes the HWDS types found in the field survey.

Table 3: Observed HWDS Types

System Type	Number
Conventional Trunk and Branch (copper)	3
Conventional Trunk and Branch (PEX)	9
Manifold w/ PEX Parallel Piping	23
Hybrid Systems w/ PEX Piping	13
Recirculation Systems (copper)	6
Recirculation Systems (PEX)	6

Pipe location was disaggregated into five categories: Attic, exterior wall cavity, garage, interior cavity (interior walls or between first and second floor), and underslab. In terms of both length and entrained volume, most of the piping (45%) was located in interior wall cavities with the attic space (37%) close behind. Exterior wall cavities, garage, and underslab each accounted for between 5 and 8% of pipe length and entrained volume.

Table 4 breaks down the pipe location data further into one and two-story categories. One-story homes primarily had piping in the attic (62% by length) and secondarily in interior wall cavities (21%). Although attic piping was the second most common pipe location for two-story homes (22%), most of the piping in two-story homes was located in interior cavities including floor cavities (59%).

Table 4: Pipe Location Variations with Number of Stories

Pipe	One-Story		Two-Story	
Location	By Length	By Volume	By Length	By Volume
Attic	62%	64%	22%	21%
Exterior Wall	7%	7%	9%	9%
Garage	4%	4%	6%	5%
Interior Cavity	21%	18%	59%	61%
Underslab	6%	7%	4%	4%

Table 5 reports the average volume of water entrained in the piping between the water heater and the end use points for the different HWDS types. For all sites, the average volume between the water heater and an end use point was 1.30 gallons. The average entrained volume for all non-recirculation systems was fairly comparable (0.86 to 0.97 gallons), although once adjusting for floor area, the parallel piping sites were ~20% less volume than the conventional systems and 9% less than the hybrid systems. The recirculation systems had by far the highest entrained volume. After normalizing by floor area, the average volume was nearly double that of the non-recirculating system types, without accounting for return line volume (average of 0.29 gallons per 1000 ft^2).

It is important to note that the volumetric data does not directly correlate to HWDS efficiency since the delivery characteristics of the various system types is very different. For example, parallel piping systems usually have a dedicated line from the hot water manifold[5] to the end use point requiring the complete purging of the line (from the manifold) before the first pulse of hot (or warm) water arrives from the water heater. This is in contrast to conventional and most hybrid systems that often share a main trunk line among most or all of the end use points. Recirculation systems also demonstrate favorable water waste and wait time benefits by effectively bringing the water heater in close proximity to the end use points[6].

Table 5: Average Entrained Hot Water Volume to End Use Points

System Type	Avg Pipe Length (ft)	Avg Volume (gallons)	Avg Vol per 1000 ft^2 of Floor Area
Conventional Trunk and Branch	185	0.86	0.49
Manifold w/ PEX Parallel Piping	499	0.97	0.39
Hybrid Systems w/ PEX Piping	227	0.89	0.43
Recirculation Systems	385	2.82	0.82

Figure 4 further disaggregates the data by HWDS type and number of stories (one and two-story denoted by “1S” and “2S”, respectively). The recirculation systems consistently demonstrate the largest entrained volume of the sample. All the other system types cluster fairly closely to an average entrained volume of 1 gallon, although the parallel piping systems demonstrate little sensitivity to floor area. This is largely due to the consistently observed characteristic of the manifold systems where excessive amounts of ¾” or 1” piping is used to connect the water heater to the manifold[7].

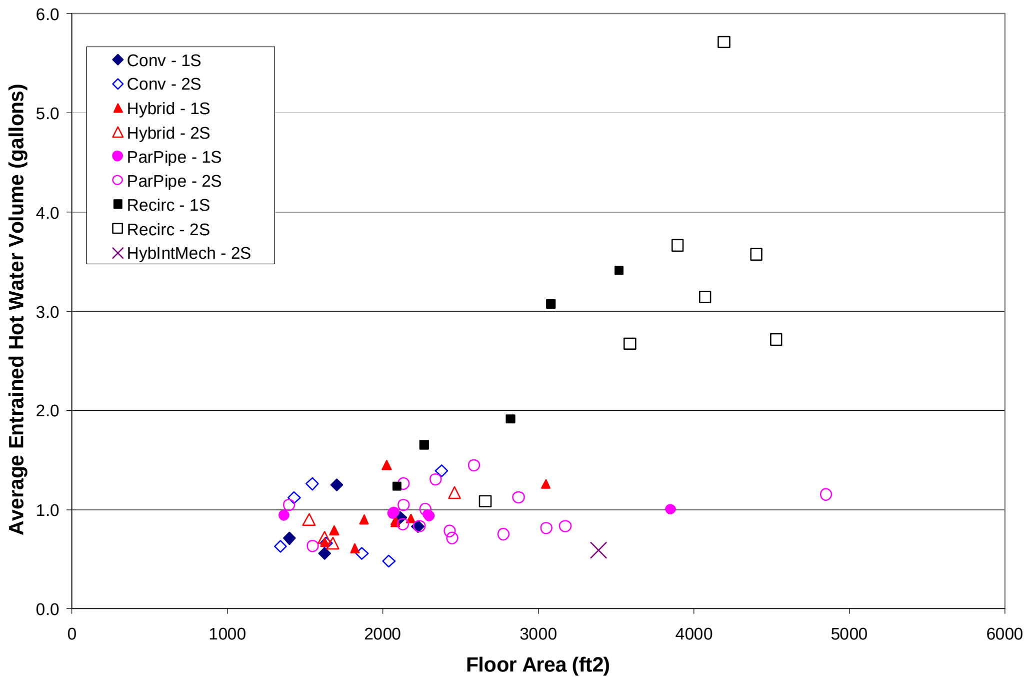
For 41 of the 60 houses surveyed, the water heater types could be precisely determined based on equipment installed in the models or information provided by plumbers and/or building superintendents. Of the 41, twenty-five were 50 gallon gas storage water heaters, six were 40 gallon gas storage units, five were 75 gallon gas storage units, and five were instantaneous gas units. It was not possible to definitively verify the remaining nineteen water heaters due to garages being locked in the model homes and lack of input from the builder.

In terms of hot water fixtures there were two key areas of interest. One concerned the installation of high-volume shower systems that use water at a significantly higher rate than conventional showerheads. None of these systems were found. In four large high-end houses we did find master showers with dual showerheads. The second fixture type

[5] Some plumbers may utilize Tees at bathroom sinks to allow sharing of one line.
[6] There is, of course, an energy impact in keeping the recirculation loop hot.
[7] On average, the twenty three manifold sites were found to have 24 feet of ¾” or 1” piping between the water heater and manifold.

of interest was the kitchen and lavatory sinks. The presence of single lever control (vs. dual handle) could be a factor in higher hot water use and energy waste since the natural position of the control is in the mixed (centered) position. As a general rule, we found bath lavatories to be dual handle control and kitchen sinks single lever.

Figure 4: Average Entrained Hot Water Volume vs. Floor Area



4 Conclusions and Recommendations

The following conclusions were generated based on the field experiences during the sixty home survey:

1. PEX has achieved significant market share in the last few years with a strong trend from copper piping to PEX piping. This was especially true in Northern California. All areas of the state where PEX is allowed show fairly rapid transition to this material. The input from plumbers who have switched to PEX is that the system is cheaper to install, can utilize less skilled labor, and is less prone to leaks.

2. Plumbers cite two reasons in not changing to PEX. First, the City of Los Angeles does not allow PEX in their jurisdiction and that prevents some other southern California jurisdictions from allowing PEX. Secondly, many plumbing contractors are reluctant to install newer products for fear of future liability and specifically cite the polybutylene failures from the 1980's as the reason not to

switch to PEX. These two reasons are slowing the transition to PEX in Southern California.

3. Systems of all types were generally not efficiently installed. The following summarizes findings on each of the system types:

Trunk & Branch and Hybrid Systems
Eliminating excessive pipe length is most important improvement that could be implemented in both trunk & branch and the hybrid system types. Installers seem to put little value on reducing pipe length despite the benefits of reduced hot water waiting time (less callbacks). Designing a system with an emphasis on reducing piping length would have lower material costs, lower installation labor costs, and would provide better performance. For some reason installers tend to run trunks parallel to framing rather than straight to where the hot water is needed. This trend adds about 40% to the length of the trunk. This isn't a trend with forced air duct systems why is it typical with plastic piping?

Parallel Piping - Manifold Systems
Eliminating excessive pipe length is also the most important improvement that can be made to parallel piping systems, but the improvement is much easier. The majority of the excess pipe length is found in the main between the water heater and the manifold. The water heater and the manifold are typically located adjacent to each other but the piping that connects the two is often routed by other than a direct route. In one case there was 24 feet of one-inch pipe between the water heater and the manifold. On average, reducing the observed length to a maximum of 10 feet would reduce the entrained volume of the manifold systems by 26%. (Reducing this length by running the main out the side of the manifold cabinet and directly to the water heater could reduce this length to about 3 feet.)

Another pipe length reduction opportunity exists for two-story houses. Some, but not all, plumbers tend to run the piping to the attic and them back down to the first floor – even if the draw point is only 10 feet away. The preferred approach would be to remain between floors.

One issue that needs further study is the energy impact of tightly bundling hot and cold piping together. This was seen in some cases. The bundling was apparently done to consolidate the tubing in one location and make the piping installation look better.

Hot Water Recirculation Systems
Eliminating excessive pipe length is also a major issue for recirculation systems. In fact the problem is more significant than for other system types since excess pipe length is usually large diameter piping (3/4" or 1"). For the twelve recirculation sites surveyed, the average recirc loop entrained volume was found to be 4.42 gallons. Return line sizing was found to average 0.99 gallons and runouts (from the loop to the fixtures) were 0.17 gallons on average. For continuous or timer controlled loops, the large loop size has significant energy impacts. For the preferred demand recirculation approach, the data reinforces the need to fully understand how these systems are installed and controlled.

The poorest performing systems in the recirculation sample appear to the three systems that were designed as hot water circulation systems but the actual installation of the pump is an option. The circulation return line is terminated inside the wall so no one but the builder can install the optional circulation pump. From our vantage point, it did not appear that the recirculation loops were to be installed. Without a pump, these oversized lines would take a minimum of seven minutes to fill the hot water line to the kitchen sink.

4. Although parallel piping systems utilize roughly twice the length of piping relative to conventional plumbing practice, the entrained volume (per unit of floor area) was the least of the four system types. Additional significant volume reductions can be achieved with parallel piping systems by shortening the length of the main line between the water heater and the manifold. A 26% average volume reduction was calculated for the manifold systems if the length of the main could be reduced to 10 feet.

5. Title 24 eligibility criteria for all system types should be carefully reviewed to insure that the systems being installed are properly credited or penalized.

6. Six house plans will be developed for use in the Title 24 analysis process. Our proposal is to have one-story plans with floor areas of 1367, 2010, and 3,080 ft^2 and two-story plans with floor areas of 1,408, 2,811, and 4,402 ft^2. The "volume/1000 ft^2" metric presented in Table 5 should be used as guidance in determining pipe lengths and pipe diameters in laying out the plumbing system.

APPENDIX A:

Site Field Summary

Site	FA	# stories	Number of Bathrooms	Number of UsePoints1	Water Heater Outlet Pipe Size	AvgVol2	Distribution System Description
1	3385	2	2.5	12	0.75	0.59	Interior WH, Manifold System (1/2" PEX) with some Tees
2	2024	1	2	12	1.00	1.45	Main with Tees and Distributed Manifolds (PEX)
3	2462	2	2.5	13	1.00	1.17	Main with Tees and Distributed Manifolds (PEX)
4	1687	1	2	11	1.00	0.79	Main with Tees and Distributed Manifolds (PEX)
5	3851	1	3.5	17	1.00	1.00	Parallel Piping Manifold System (3/8' & 1/2" PEX)
6	4852	2	3.5	15	1.00	1.15	Parallel Piping Manifold System (3/8' & 1/2" PEX)
7	2075	1	2	11	1.00	0.97	Parallel Piping Manifold System (3/8' & 1/2" PEX)
8	2301	1	2	12	1.00	0.93	Parallel Piping Manifold System (3/8' & 1/2" PEX)
9	2875	2	3	14	1.00	1.12	Parallel Piping Manifold System (3/8' & 1/2" PEX)
10	2065	1	2	12	1.00	0.96	Parallel Piping Manifold System (3/8' & 1/2" PEX)
11	2291	1	2	12	1.00	0.95	Parallel Piping Manifold System (3/8' & 1/2" PEX)
12	3175	2	4	16	1.00	0.83	Parallel Piping Manifold System (3/8' & 1/2" PEX)
13	2113	1	2	11	0.75	0.92	Conventional Trunk and Branch (PEX)
14	1704	1	2	10	0.75	1.25	Conventional Trunk and Branch (PEX)
15	2377	2	3	14	0.75	1.39	Conventional Trunk and Branch (PEX)
16	2236	2	2.5	12	0.75	0.83	Parallel Piping Manifold System (3/8' & 1/2" PEX)
17	2433	2	3	14	0.75	0.78	Parallel Piping Manifold System (3/8' & 1/2" PEX)
18	2779	2	3.5	15	0.75	0.75	Parallel Piping Manifold System (3/8' & 1/2" PEX)
19	2589	2	3	14	1.00	1.44	Parallel Piping Manifold System (3/8' & 1/2" PEX)
20	3053	2	4.5	18	1.00	0.81	Parallel Piping Manifold System (3/8' & 1/2" PEX)
21	1866	2	2.5	12	0.75	0.56	Conventional Trunk and Branch (PEX)
22	1677	2	2.5	10	0.75	0.66	Main with Tees and Distributed Manifolds (PEX)
23	2038	2	3	13	0.75	0.48	Conventional Trunk and Branch (PEX)
24	1552	2	2.5	11	0.75	0.63	Parallel Piping Manifold System (3/8' & 1/2" PEX)
25	1367	1	2	10	0.75	0.94	Parallel Piping Manifold System (3/8' & 1/2" PEX)
26	2131	2	2.5	11	0.75	0.85	Parallel Piping Manifold System (3/8' & 1/2" PEX)
27	1340	2	2.5	11	0.75	0.63	Conventional Trunk and Branch (PEX)
28	1525	2	2.5	10	0.75	0.90	Main with In-line Manifolds (PEX)
29	1623	2	2.5	11	0.75	0.72	Main with In-line Manifolds (PEX)
30	2136	2	2.5	12	0.75	1.04	Parallel Piping Manifold System (3/8' & 1/2" PEX)
31	2448	2	3	13	0.75	0.71	Parallel Piping Manifold System (3/8' & 1/2" PEX)
32	2276	2	3	13	0.75	1.00	Parallel Piping Manifold System (3/8' & 1/2" PEX)
33	1398	2	2.5	12	1.00	1.04	Parallel Piping (Interior) Manifold System (1/2" PEX)
34	2136	2	2.5	12	1.00	1.26	Parallel Piping (Interior) Manifold System (1/2" PEX)
35	2341	2	2.5	12	1.00	1.30	Parallel Piping (Interior) Manifold System (1/2" PEX)
36	1400	1	2	9	0.75	0.71	Conventional Trunk and Branch (PEX)
37	1626	1	2	9	0.75	0.56	Conventional Trunk and Branch (PEX)
38	2224	1	2	10	0.75	0.83	Conventional Trunk and Branch (PEX)
39	2082	1	3	13	0.75	0.89	Main with Tees and Distributed Manifolds (PEX)
40	1820	1	2	10	0.75	0.61	Main with Tees and Distributed Manifolds (PEX)
41	1626	1	2	9	0.75	0.67	Main with Tees and Distributed Manifolds (PEX)
42	3082	1	3.5	15	1.00	3.07	Pre-Plumbed Recirc Loop with In-line Manifolds (PEX)
43	2823	1	4.5	17	1.00	1.91	Pre-Plumbed Recirc Loop with In-line Manifolds (PEX)
44	3522	1	4.5	17	1.00	3.41	Pre-Plumbed Recirc Loop with In-line Manifolds (PEX)
45	2092	1	2.5	12	0.75	1.23	Underslab Recirc Loop (PEX) w/ Time/Temp
46	2267	1	3	13	0.75	1.65	Underslab Recirc Loop (PEX) w/ Time/Temp
47	2660	2	2.5	13	0.75	1.08	Underslab Recirc Loop (PEX) w/ Time/Temp
48	2081	1	2	10	0.75	0.87	Hybrid System with Trunks, Tees, and Manifolds
49	1880	1	2	10	0.75	0.90	Hybrid System with Trunks, Tees, and Manifolds
50	2180	1	2	10	0.75	0.91	Hybrid System with Trunks, Tees, and Manifolds
51	3048	1	2.5	13	1.00	1.26	Hybrid System with Trunks, Tees, and Manifolds
52	3591	2	4.5	16	1.00	2.67	Demand Recirc System (Copper)
53	3897	2	4.5	16	1.00	3.66	Demand Recirc System (Copper)
54	4195	2	4.5	17	1.00	5.71	Demand Recirc System (Copper)
55	1545	2	2.5	12	0.75	1.26	Conventional Trunk and Branch (Copper)
56	1635	2	2.5	11	0.75	0.66	Conventional Trunk and Branch (Copper)
57	1430	2	2.5	11	0.75	1.12	Conventional Trunk and Branch (Copper)
58	4073	2	3.5	17	1.00	3.14	Overhead Recirc Loop (Copper) w/ Time/Temp
59	4402	2	5.5	21	1.00	3.57	Overhead Recirc Loop (Copper) w/ Time/Temp
60	4533	2	5.5	22	1.00	2.71	Overhead Recirc Loop (Copper) w/ Time/Temp
Avg	2432	1.58	2.84	12.85	0.86	1.30	
StDev	868						
Max	4852						
Min	1340						

1=	includes all hot water use points; combination tub/shower is treated as individual use points
2=	average volume between the water heater and all hot water use points in the house

CALIFORNIA CLIMATE ZONES